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RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	6/28/99	Initial issue (as FEM)	Doug Volkman, *PM-2*	Dennis McLain, *FWO-FE*
1	2/9/04	Changed FEM to ESM; Incorporated IBC & ASCE 7 in place of UBC 97; Incorporated DOE-STD-1020-2002 in place of DOE-STD-1020-94; Incorporated concepts from DOE O 420.1A. General revision and improvements.	Mike Salmon, *FWO-DECS*	Gurinder Grewal, *FWO-DO*

RESPONSIBLE ENGINEERING STANDARDS POC AND COMMITTEE

for upkeep, interpretation, and variance issues

Ch. 5, PT. I	**Structural POC/Committee**

I GENERAL CRITERIA FOR ALL LANL STRUCTURES

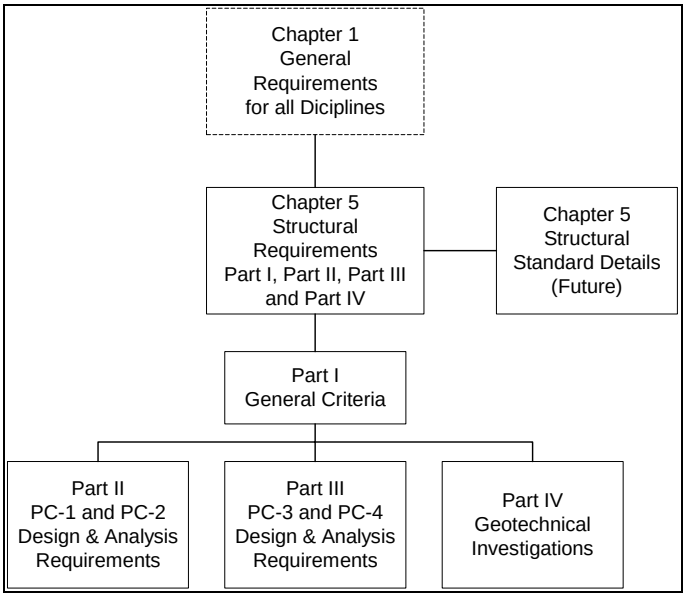
1.0 USE OF THIS CHAPTER

1.1 Purpose

A. This Chapter of the Los Alamos National Laboratory (LANL) Engineering Standards Manual (ESM) presents structural design criteria that are unique to LANL. The criteria presented herein are in addition to nationally accepted design criteria for structures. In general, the International Building Code *(currently IBC, 2003)* shall be the code of record for the design of structures, systems, and components (SSCs) at LANL.[1] In addition, these criteria implement the natural phenomena hazards mitigation requirements in DOE Order 420.1A (Facility Safety) that are applicable to all Department of Energy (DOE) nuclear and non–nuclear facilities.

B. This Chapter presents the requirements of the DOE Orders and implementing standards specific to LANL so that design engineers not familiar with DOE requirements may utilize this as a source document without referring to the parent Orders, Standards, and Guidance documents. This Chapter provides overall requirements and guidance for developing structural designs. The design organization is responsible for providing the complete design package including drawings, specifications, and a design basis document and other documentation as described in this Chapter. Goals for design basis documentation include:

- Achieve uniformity in documentation for LANL structure designs.
- Provide assurance that LANL specific loads are addressed.



[1] New Mexico building code criteria shall be used where requirements are more stringent than IBC requirements.

C. *Guidance: This Chapter also implements the DOE and LANL policy of a graded approach applied to structural design. Per LANL requirements (LIR 230-01-02 and LIG 230-01-02), facility work is subjected to a level of management control commensurate with the importance of the work to safety, environmental compliance, safeguards and security, programmatic importance, magnitude of hazard, and financial impact. At LANL, the graded approach is implemented in Management Levels (ML). The greatest level of management control and rigor is exercised for ML-1 with the least level for ML-4. From a structural design standpoint with respect to safety, ML-1 SSCs are normally those designated as safety class for Hazard Category 2 and 3 nuclear facilities or serve to provide protection to the public for non-nuclear facilities. ML-2 SSCs are those designated as safety significant for Hazard Category 2 and 3 nuclear facilities or provide worker protection or significant protection against the uncontrolled release of hazardous materials from non-nuclear facilities. ML-3 SSCs are important to safety but their failure would have only minimal off-site impact. ML-4 SSC failure could neither cause nor allow any significant health effects to workers or the public. DOE requirements and guidance for implementation of a graded approach are implemented in design for natural phenomena hazards (NPH) through the designation of Performance Categories (PC) as defined in DOE O 420.1A (Facility Safety), DOE G 420.1-2 (Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities), DOE-STD-1021 (Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components), and DOE-STD-1020 (Natural Phenomena Hazards Design and Evaluation Guidelines for Department of Energy Facilities) are discussed in the following section. This Chapter utilizes the NPH performance categories for assigning the appropriate structural design requirements. LANL Management Level designations and requirements must also be included for structure design projects.*

1.2 DOE Natural Phenomena Hazard Mitigation Requirements

A. *Guidance: Natural phenomena hazard mitigation objectives defined in Section 4.4 of DOE O 420.1A are to ensure that DOE facilities are designed, constructed, and operated so that the general public, workers, and the environment are protected from the impact of Natural Phenomena Hazards (NPHs). The provisions in the Order apply to DOE sites and facilities and cover all natural phenomena hazards such as seismic, wind, flood, and lightning. Where no specific requirements are specified, model building codes or national consensus industry standards shall be used.*

B. Natural phenomena mitigation design requirements are presented in Section 4.4.2 of DOE O 420.1A and are repeated as follows. Systems, structures, and components shall be designed, constructed, and operated to withstand the effects of natural phenomena as necessary to ensure the confinement of hazardous material, the operation of essential facilities, the protection of government property, and the protection of life safety for occupants of DOE buildings. The design process shall consider potential damage and failure of structures systems, and components due to both direct and indirect natural phenomena effects, including common cause effects and interactions from failures of other systems, structures, and components.

C. Section 4.4.2 continues with: Systems, structures, and components for new DOE facilities, and additions or major modifications to existing systems, structures, and components shall be designed, constructed, and operated to meet the requirements in the previous paragraph. Any addition and modifications to existing DOE facilities shall not degrade the performance of existing systems, structures, and components to the extent that the objectives in this Section cannot be achieved under the effects of natural phenomena.

D. *DOE G 420.1-2 (Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear and Non-Nuclear Facilities) notes that a key element of DOE NPH mitigation requirements is the use of a graded approach. DOE facilities are diverse enough to warrant a graded approach (e.g., some are office buildings while others contain substantial inventories of hazardous material). Such an approach recognizes the diversity of objectives for NPH protection, the diversity of facilities, and the diversity of measures that are appropriate to ensure suitable NPH protection. When properly developed and implemented, a graded approach optimizes the allocation of effort and resources.*

E. The graded approach is implemented by assigning structures, systems, and components to Performance Categories depending on facility characteristics and defining several sets of NPH design/evaluation provisions with increasing conservatism (i.e., producing a decrease in probability of damage or failure to perform the intended safety function). Five Performance Categories are defined in DOE G 420.1-2 ranging from PC 0 through PC 4. PC 0 SSCs are of little safety importance and have no NPH design requirements. PC 1 and PC 2 NPH requirements are similar to those of model building codes and PC 3 and PC 4 NPH requirements approach those for commercial nuclear power plants.

F. *Guidance: Specific design criteria for DOE facilities for each Performance Category are provided in DOE-STD-1020. These criteria are adapted for design of LANL facilities in this Chapter.*

1.3 Applicability

A. The requirements of this Chapter shall be applied to the design of new structures, systems, and components. In addition to new structural designs, this Chapter applies to renovation, replacement, modification, maintenance, or rehabilitation projects. Applicability of the provisions of this Chapter is illustrated in Table I-1.

1.3.1.1 Table I-1, Applicability of LANL ESM Chapter 5 and IBC to Structural Design

Item	ESM Chapter 5 Applicable?
New Structures	Yes
New Non-Structural Systems & Components in New and Existing Structures	Yes, for anchorage and support design[2]

2 This chapter primarily covers the design of supports and anchorage of nonstructural systems and components. This includes complete requirements for the seismic design of those supports and anchorage. In addition, the chapter does provide some information and requirements for the seismic design of the systems and components.

Item	ESM Chapter 5 Applicable?
Replacement of Existing Facilities	Yes
Renovations, Modifications, Repairs, Alterations, or Rehabilitation to Existing Structural Systems and Sub-systems	Yes[3]
Existing Facility Safety Basis Change	Yes, the existing and new SSCs shall be evaluated against these criteria
New anchorage or support for existing systems and components	Yes, for anchorage or bracing only
Structures, Systems, & Components that are ML-4 and PC-0	No

B. These criteria are intended to be used in the design of structures and structural supports for equipment and distribution systems by licensed structural design engineers. The structures, systems, and components (SSCs) shall be assigned to NPH performance categories by LANL prior to performing the structural design. Note that over the course of the structural design, some SSCs may be reclassified in higher performance categories due to system interaction effects as discussed in Section 2.5 of DOE-STD-1021 [2]. SSCs reclassified into higher performance categories will need to be checked against the corresponding higher NPH loads. The appropriate Performance Category is a function of the safety or mission importance of the SSC. Criteria are presented in this chapter for:

- PC 1 and PC 2 structures
- Structural support and anchorage of PC 1 and PC 2 systems and components
- PC 3 and PC 4 structures
- Structural support and anchorage of PC 3 and PC 4 systems and components

3 Existing structural systems and sub-systems shall be assessed for their ability to perform in accordance with the intent of current codes and this Chapter when structural or non-structural work is planned for an existing building that exceeds 50% of the estimated replacement value of the building. If the structural system or sub-systems fail the assessment, then the entire building shall be brought into compliance with current codes and this Chapter. Also, the entire building shall be brought into compliance with current codes and this Chapter for work planned for an existing building that does not exceed 50% of the estimated replacement value of the building if, in the judgment of the LANL structural engineering authority having jurisdiction, it is deemed necessary.

C. This Chapter is not intended for the design of non-structural systems and components. Refer to other chapters of the ESM for criteria that govern the design of electrical and mechanical components, including pressure vessels. The design requirements for the systems and components such as distribution systems or equipment (other than the support and anchorage) are presented in Chapter 2 (Fire Protection), Chapter 6 (Mechanical) and Chapter 7 (Electrical) as appropriate. This Chapter does address the structural and seismic analysis aspects of fire protection, mechanical and electrical equipment and distribution systems.

D. This chapter presents structural design criteria to be used in the design of structures and component supports against the effects of gravity loads, normal operating loads, natural phenomena hazard loads, and blast loads. The chapter presents minimum antiterrorism requirements as specified by the Department of the Defense [46]. Minimum antiterrorism requirements should be considered for all facilities to the extent it is not cost prohibitive, but particular attention should be paid to antiterrorism requirements for those highly visible facilities or Hazard Category 2 or 3 nuclear facilities. The provisions in this chapter for blast are focused on structural design for blast loads. Blast loading criteria will be provided by LANL. These blast loads may either be intentional, as is the case for an experimental facility, or they may be accidental. LANL conducts experiments involving explosions and, for some of these experiments, a containment structure is provided to limit explosion effects on the surrounding area. The design of such containment structures is not within the scope of this chapter.

1.4 Exclusions

A. The provisions of this ESM apply to all LANL nuclear and non-nuclear facilities that are regulated by DOE. The following exclusions to the provisions of the ESM are taken from DOE O 420.1A.

1. Activities that are regulated through a license by the Nuclear Regulatory Commission (NRC) or a State under an agreement with the NRC, including activities certified by the NRC under Section 1701 of the Atomic Energy Act;
2. Activities conducted under the authority of the Director, Naval Nuclear Propulsion Program, pursuant to Executive Order 12344, as set forth in Public Laws 98-525 and 106-65;
3. Activities conducted under the Nuclear Explosives and Weapons Safety Program relating to the prevention of accidental or unauthorized nuclear detonations to the extent a requirement under DOE O 420.1A and this Manual cannot be implemented for a particular facility in a manner that does not compromise the effectiveness of such activities;
4. Activities that are regulated by the Department of Transportation pursuant to 49 CFR 173.7(b).

1.5 Chapter Contents and Conventions

A. This Chapter consists of four sections. Sections I, II, and III provide the structural design and analysis criteria for structures, systems, and components (SSC) at LANL. Section I provides general guidance, criteria, and background on structural design, quality assurance, and design documentation. Sections II and III provide more prescriptive criteria to be used in the actual structural design. Due to similarity of PC 1 and PC 2 NPH requirements, they are addressed together in this Chapter. Similarly, PC 3 and PC 4 NPH requirements are also addressed together in this Chapter. Section II addresses the design of PC 1 and PC 2 structures and the design of the structural support and anchorage of PC 1 and PC 2 systems and components. Section III addresses the design of PC 3 and PC 4 structures and the design of the structural support and anchorage of PC 3 and PC 4 systems and components. Section IV provides geotechnical requirements.

B. All text in regular type indicates mandatory requirements unless prefaced with wording identifying it as guidance or a recommendation. Where appropriate, guidance is provided to aid the cost-effective implementation of site-specific requirements and the requirements in the applicable codes. *Italicized* text identifies recommended guidance (not mandatory), based on good business practice and through lessons-learned at LANL. Footnotes throughout the chapter add commentary or additional background information on the basis of particular provisions.

1.6 Project Records for Structural Design

A. **Project Requirements for Structural Designs:**

1. This chapter (structural) of the ESM along with applicable building codes, DOE Orders and Standard, and applicable material standards and design manuals provide the basic project requirements for structural design projects. In addition, there are generally project specific design requirements provided by LANL. Project specific requirements may be in the following form:

   - Design bid package including the Request for Proposal (RFP)
   - Project functional requirements.
   - Facility safety analysis reports.
   - Project design criteria

2. All of these project requirements shall be referenced, where applicable, in the project submittals to LANL.

B. **Project Submittals:**

1. Project records for structural design shall be prepared considering the concept of a graded approach where the level of detail and rigor is consistent with the importance to safety, mission importance, and project cost. The greatest level of detail and rigor is required in the design and documentation for facilities, structures, systems, and components that are in ML-1 or ML-2 projects or are in systems designated as PC-3 or PC-4. Lesser level of detail is acceptable for SSCs in ML-3 or ML-4 projects or in systems designated as PC-1 or PC-2. Extensive documentation is generally required for the structural design of new buildings.

2. If such buildings are classified as PC-3 or PC-4, the structural design will be performed under close scrutiny of LANL and DOE reviewers such that the level of documentation is especially important and extensive documentation will generally be required. However, many LANL structural design projects may be simple efforts involving modifications to portions of buildings or installation of new equipment or systems in existing buildings. For these types of projects, it may be possible to document the structural design by drawings with notes along with structural calculations. For all structural design projects, large or small, all of the information described in this section must be documented in some manner.
3. The project records for structural design to be submitted to LANL shall consist of the following:
    - Design Basis Document (DBD)
    - Structural Calculations
    - Test and Inspection Requirements
    - Project Quality Assurance (QA) Plan
    - Construction Drawings
    - Construction Specifications
4. At a minimum, the Design Basis Document (DBD), construction drawings, and construction specifications shall be submitted to LANL for review. The review is conducted by the LANL Engineering Standards Chapter 5 Point of Contact (POC), or his designee, as the structural authority having jurisdiction for review and approval.
5. Construction documents shall comply with the applicable sections of the New Mexico Engineering and Surveying Practice Act (Chapter 61, Article 23-21, Paragraph B, NMSA 1978).[4] The New Mexico professional engineer in charge and directly responsible for the structural engineering work shall seal and sign the design basis document, construction drawings, construction specifications, structural calculations, and test and inspection requirements.

C. **Design Basis Documents:**

1. A design basis document (DBD) shall be prepared. The DBD provides a summary of the specific facility structural design basis and shall include the performance category of the structures, systems, and components being designed, design codes of record (dates and editions), methods (computer codes, analytical methods), load definition, load combinations, member capacity equations, and corresponding applicable acceptance criteria. The DBD shall describe the design of building structures, non-structural components, equipment, and distribution systems. A sample format for a DBD is presented in Figure I-1.
2. The design basis document may be used to eliminate load combinations as described in Sections II and III from consideration by showing that they are either not applicable or bounded by other load combination equations. Once the design basis document is established, **it does not** have to be revisited during the project duration for changes or updates in the ESM or the referenced standards unless otherwise noted in the LANL Work Smart Standards Set.[5]

4 This section of the act is currently scheduled to be repealed effective July 1, 2006.
5 This provision is included in order that once the design basis is established for a given project, the

- Facility Background and Mission*
- Facility Hazard Classification and Basis per LIR 300-00-05*
- Management Level for the Project per LIR 230-01-02 and LIG 230-01-02*
- Assignment of SSCs as Safety Class, Safety Significant, or Important to Safety and Assignment of SSCs to NPH Performance Categories*
- Facility Siting Considerations (standoff distance from known faults, flood levels, etc.)*
- Natural Phenomena Hazard Definition
- Earthquake (DBE ground response spectra)
- Wind (peak gust speed)
- Wind Driven Missiles (definition)
- Snow
- Flood and local precipitation (if applicable or basis for not considering)
- Antiterrorism Measures*
- Experimental Explosion Design Considerations
- Accidental Explosion Design Considerations
- LANL ESM Revision and Edition
- Design Codes and Standards of Record (Edition and Rev. Date)
- Rationale for Selection of Structural Systems
- Analysis Methodology (Determination of Structural Demand)
- Member Capacity Equations Not Included in Design Codes or Not Commonly Used
- Load Combinations (May Refer to Chapter 5 of the ESM)
- Means of accounting for inelastic behavior during the DBE in the Seismic Analysis and in Design Detailing

* This information is typically found in other documents such as the Facilities Design Description (FDD) or System Design Description (SDD) and only a brief summary from these documents need by included in the DBD.

Figure I-1, Design Basis Document Sample Format

3. In addition to describing the design basis for gravity loads, normal operating loads, and natural phenomena hazard loads, the DBD shall describe the design basis for blast loads and antiterrorism measures implemented. Blast loads can result from either planned experiments or accidents involving explosives or flammable materials. The design blast loads, methods of analysis, and levels of acceptable blast damage shall be addressed in the DBD. Antiterrorism measures follow the minimum standards from the Department of Defense [46] and shall also be addressed in the DBD.

design and construction criteria would be fixed and the problem of revising or reviewing calculations and other design documentation to a moving criteria target is not necessary.

4. An SSC must be assigned a Performance Category (PC) to establish the appropriate natural phenomena hazard (earthquake, wind, and flood) design and analysis requirements as put forth in DOE-STD-1020 [1]. This standard provides design criteria for four performance categories, PC-1 through PC-4. The assignment of NPH performance categorization is accomplished using the guidance established in DOE-STD-1021 [2] (Natural Hazard Performance Categorization). The basis for assignment of performance categories to SSCs shall be either summarized or presented in detail in the DBD. The assignment of performance categories may be summarized when a safety analysis report exists that contains the detailed information. The assignment of performance categories shall be presented in detail when a separate document, such as a safety analysis report, does not present the basis for assignment of performance categories. NPH performance categories will be provided to the structural designer by LANL.
5. A separate DBD is required for major structural design projects. Where the ESM is employed for the design of small buildings, equipment slabs, or structural components, etc., the contents of the DBD, as described above, may be included as front matter in the structural calculations.[6]

D. **Structural Calculations:**

1. Structural calculations shall be performed, numbered and approved in a consistent format as described in the Project QA Plan (see Section I.2.E) and shall include, at a minimum, sections for Purpose and Objective, Methodology and Acceptance Criteria, Assumptions, Design Input, References, Calculations and Summary and Conclusions. *When calculations are performed by computer analysis, the computer files may be included in Attachments/Appendixes to the Calculation*. Computer analyses shall conform to the requirements given below. *Two acceptable procedures for performing calculations for LANL include CMRU-AP-002 [30] and FWO Procedure-603 [31]*. Structural Calculations shall be signed by a preparer, checker (that attests to numerical accuracy) and approver (attests to reasonableness of the theory and assumptions and to the validity of the conclusions reached). The checker and approver may be the same individual but not the preparer. All structural design calculations shall be performed following a LANL approved QA program. The requirements of the QA program may be tiered for the various NPH performance categories by the graded approach philosophy.

6 The majority of LANL structural design projects are small and will not require a formal DBD.

2. *Calculations may be performed by computer analysis.* When computer analysis is performed, input and output shall be numbered in a consistent format as described in the Project QA Plan. The documentation for the computer analysis shall be included in the overall calculation, as described above. *Computer Input and Output may be included in Attachments/Appendixes to the Calculation.* Preparer, Checker and Reviewer requirements are as described above. The documentation for computer analysis shall, at a minimum, include a brief description of the structural model, the loading, a figure showing the model configuration [with control nodes shown along with the most limiting structural components (members)], and how the results of the analysis are applied. The analysis input file and condensed output files directly used to support the analysis results shall be included. Additional output files may either be included or stored in an electronic format. Documentation shall be sufficient to insure that a third party may take the input file and reproduce the analysis results. Also, documentation shall be sufficient to the extent that the reviewer can determine that the model is valid and that the results were properly interpreted.

E. **Test and Inspection Requirements:**

1. Special inspection, test, and structural observation requirements shall be provided on the drawings and in the specifications for new construction or modifications to existing SSC's. Minimum requirements for special inspection, testing, and structural observation are given in Sections 1704, 1708, and 1709, respectively, of the IBC. The special inspection, test, and structural observation requirements should be conducted within the framework of a graded approach with an increasing level of rigor employed from PC-1 to PC-4 SSC's. The goal of these requirements is to ensure that construction is implemented in the manner intended by the structural design engineer.

F. **Project Quality Plans**

The following sections describe the QA and Peer Review requirements for the structural aspects of a project. The QA and peer review should be conducted within the framework of a graded approach with increasing level of rigor employed from PC-1 to PC-4 facilities. These requirements shall be documented in a Project Quality Plan. A sample format covering the required structural design elements of a project for the Project Quality Plan is presented in Figure I-2.

1. **Quality Assurance Requirements:**

a. The LANL basic quality assurance (QA) requirements are put forth in DOE Order 414.1A (CHG 1) [15] (Section 4.6 deals with Design QA) and, for nuclear facilities, the Code of Federal Regulations, 10 CFR Part 830, Subpart A, Quality Assurance Requirements [14]. A QA program that, at a minimum achieves the DOE/LANL QA requirements for specifications, drawings, procedures and instructions shall be used. The basic elements of the structural analysis and design QA program shall address the following:

- Design Organization: Analysis team, division of responsibility, team interface control, and organizational procedures and standards.
- Design Procedures
- Design Basis Document
- Methods for Design Verification

- Design reviews and independent peer review
- Design output documents, i.e., drawings, specifications, and calculations
- Design document control

b. The QA program shall at a minimum include provisions for verifying and checking the adequacy of the analysis and design either by directly checking the original analysis and verifying the underlying assumptions, or by use of alternate or simplified calculation methods or the performance of a suitable testing program or by the performance of design reviews.

QA PLAN

- QA Requirements for Project (May refer to a manual, rev. and date)
- Project and QA Team Qualifications
- QA Training Requirements
- Design Basis Document Requirements
- Design Procedures
- Calculation Requirements (may refer to a LANL specification)
- Computer Analysis Requirements (may refer to a LANL specification)
- Inspection, Observation, and Testing Requirements
- Drawing/Specification Requirements (Including PE Stamp requirements)
- Document Control
- Design Review and Independent Peer Review
- Application of Graded Approach for QA Process

PEER REVIEW PLAN

- Peer Reviewer Qualifications
- Scope of Peer Review Process (When, What and Where)
- Format of Final Report from Peer Reviewer
- Application of Graded Approach for Peer Review Process

Figure I-2, Structural Design Project Quality Plan Sample Format

2. **Peer Review Plan**

   a. Qualified LANL staff will review PC-1 facilities and PC-1 SSC. Qualified LANL staff or external expert consultants, hired by the Laboratory, will be engaged to peer review the design and analysis of PC-2, PC-3 and PC-4 facilities. In all cases, the project peer reviewer shall not be engaged in design activities for the project. Peer review is in addition to the design review performed in the QA portion of the project and provides an independent evaluation of the design. Peer review shall be performed by either internal and/or external personnel with recognized technical credentials concerning the unique features of the design and analysis. The peer review effort may be performed in series or in parallel with the design or analysis process. *However, for most projects, it is recommended that peer review should be performed in parallel.*[7] The Peer Review Plan will include the requirements for Structural Calculations, Computer Analyses, and Test and Inspection Requirements as discussed above.

   b. A graded approach shall be used so the scope of the review, including the number of reviewers engaged, is consistent with the complexity of the design, the number of disciplines involved, and the uncertainty in the data.

   c. Detailed guidelines and checklists for conducting a peer review shall be developed based on the Project Peer Review Guidelines contained in Ref. [38]. Peer Review of the analysis of the structural system used to verify the proposed design should consider the following elements:

   - Applied loads
   - Adequacy of model
   - Assumptions upon which the model is based
   - Use of the results from the analysis
   - Appropriateness of the solution technique or analysis software
   - Adequacy of horizontal and vertical load paths
   - Proper inclusion of the geotechnical investigation into the analysis

G. **Drawings:**

1. Drawings for new design and modifications to existing design shall be prepared in accordance with the LANL Drafting Manual. Applicable codes and manuals and design criteria shall be provided on the general structural notes sheet of the drawing set. Codes and manuals and project design requirements, including their edition or date, used for the structural design shall be listed. Also, vertical (e.g., dead load, live load, etc.), horizontal (e.g., wind loads), and seismic loads used in the design shall be listed.

7 For large projects, it is recommended that the peer review effort should at least include a review of the DBD, sample calculations performed early in the project, specialized or unique calculations and the final documentation at the end of the project. This enables the peer review effort to have a positive effect on the project throughout and minimizes re-work and surprises at the end of the project.

H. **Specifications:**

1. Specifications for new design and modifications to existing design shall be prepared to provide project specific construction requirements associated with the structural design of the building and the construction/installation of supports and anchorage for systems and components. The specifications shall include all applicable requirements in the templates provided in the LANL Construction Specifications Manual.[8]

1.7 Codes and Standards

A. The Standards and Manuals discussed in A to D below are not intended to cover all requirements necessary to provide a complete operating facility. The engineer/designer should review the project specific requirements to identify additional requirements. Project specific requirements are provided by LANL.

B. If there is a conflict between codes, standards, and LANL requirements such as this manual or project specific requirements, contact the LANL Engineering Standards Chapter 5 POC for assistance in resolving the conflict. If a requirement in any LANL document exceeds a minimum code or standard requirement, it is not considered a conflict, but a difference, so comply with the most stringent requirement among the LANL documents. Exemptions from these criteria may be granted by the LANL Engineering Standards Chapter 5 POC, and will be considered on a case by case basis.

C. Questions concerning the contents in these standards and manuals should be addressed to the LANL Engineering Standards Chapter 5 POC. These standards and manuals are available on the World Wide Web at http://www.lanl.gov/f6stds/pubf6stds/xternhome.html

1. **Work Smart Standards**: LANL Environmental Health and Safety Work Smart Standards (WSS) are contained in Appendix G of the University of California/DOE Contract. Comply with the edition and addenda(um) in effect on the effective date noted in the Work Smart Standards set, unless otherwise noted, and the latest edition of the CFRs. A copy of the WSS set is available from the LANL Standards Program.

2. **LANL Engineering Standards Manual (ESM)**: The LANL Engineering Standards Manual (ESM), arranged by discipline specific chapters, provides site-specific engineering requirements and guidance for LANL facilities.

3. **Construction Specifications Manual**: The Construction Specifications Manual provides templates for the preparation of project specific construction specifications at LANL. These documents are referenced throughout the ESM. The specifications shall be edited to reflect the scope of the project. Variances taken by the engineer/designer for a portion of an applicable Construction Specification Template shall be approved by the LANL Engineering Standards Chapter 5 POC.

4. **Drafting Manual**: The Drafting Manual provides drafting requirements for use when creating or revising construction drawings for LANL construction projects and preparing as-built drawings.

8 For small structural design projects, specifications may be in the form of notes on the drawings.

5. **Codes of Record and Additional References**: The user of the ESM shall comply with the code edition referenced herein (Subsection I.7) or the latest edition at the time of design contract award (or design initiation in the case when LANL staff is performing the design or evaluation). That same code edition shall be used throughout the projects' design and construction, (unless otherwise noted in the LANL Work Smart Standards Set). The DBD shall identify the exceptional cases where LANL WSS Set code editions updated while project design and construction phases are ongoing shall take precedence over code editions in effect at project start. The edition of the codes and standards used in the design shall be referenced in the DBD as noted in Section 1.2.B. The codes, standards, laws, orders, and additional references (publications and papers) presented in Subsection I.7 are used in the evaluation of SSC's as described in this Chapter. If there is a conflict between the referenced codes, standards, and LANL structural design requirements in this manual, contact the LANL Engineering Standards Chapter 5 POC for assistance in resolving the conflict. If there is a conflict between the referenced books, papers and report, and LANL structural design requirements in this manual, the LANL ESM requirements shall govern.[9]

2.0 ACRONYMS AND NOTATIONS

The following is a list of acronyms, notation, symbols, and shortened titles used in this Engineering Standards Manual. Load related symbols and factors are defined in Section II.1A and III.1A.

AASHTO – American Association of State Highway and Transportation Officials

ACI – American Concrete Institute

ADM – Aluminum Design Manual

AF&PA – American Forrest & Paper Association

ANSI – American National Standards Institute

API – American Petroleum Institute

ASCE – American Society of Civil Engineers

ASD – Allowable Stress Design

AWS – American Welding Society

BLEVE – Boiling Liquid Expanding Vapor Explosion

CCPS – Center for Chemical Process Safety

CDFM – Conservative Deterministic Failure Margin

CFR – Code of Federal Regulations

CMAA – Crane Manufacturers Association of America

9 The papers, books and reports referenced are normally used in this Chapter for narrow technical issues. The provisions of this Chapter are included to be consistent with the governing consensus code or standard not individual papers, books or reports.

CRSI – Concrete Reinforcing Steel Institute

DBD – Design Basis Document

DBE – Design Basis Earthquake

DBFL – Design Basis Flood

DOE – Department of Energy

DOE-STD – Department of Energy Standard

EPRI – Electric Power Research Institute

ESM – LANL Engineering Standards Manual

F_μ - Inelastic Energy Absorption Factor

FEMA – Federal Emergency Management Agency

FWO-DECS – Facility & Waste Operations Division, Design Engineering and Construction Services Group

GIP – Generic Implementation Procedure for Seismic Verification of Nuclear Plant Equipment

HCLPF – High Confidence of Low Probability of Failure

HVAC – Heating Ventilation and Air Conditioning

I – Importance Factor

IBC – International Building Code

IMRF – Intermediate Moment Resisting Frame

LANL – Los Alamos National Laboratory

LRFD – Load and Resistance Factor Design

MBMA – Metal Building Manufacturers Association

ML – Management Level

MMRWF – Masonry Moment Resisting Wall Frame

NDS – National Design Specification

NEHRP – National Earthquake Hazards Reduction Program

NPH – Natural Phenomena Hazard

NRC – Nuclear Regulatory Commission

OMRF – Ordinary Moment Resisting Frame

PC – Performance Category

PGA – Peak Ground Association

POC – Point of Contact

QA – Quality Assurance

R – Response Modification Coefficient

RMI – Rack Manufacturers Institute

RRS - Required Response Spectra

SAM- Seismic Anchor Motion

SD – Strength Design

SDI – Steel Deck Institute

S_{DI} – Response Spectral Acceleration at 1 Second Period

S_{DS} – Peak Response Spectral Acceleration (0.2 Second Period)

SJI – Steel Joist Institute

SMRF – Special Moment Resisting Frame

SRSS – Square Root Sum of the Squares

SSI – Soil Structure Interaction

SSC – Structures, Systems, and Components

SSRI – Steel Storage Rack Institute

TRS - Test Response Spectra

TNT – trinitrotoluene

W – Effective Seismic Weight

WSS – Work Smart Standards

Zero Period Acceleration (ZPA)

Ω_0 – System overstrength coefficient

ρ - Redundancy coefficient for the structure

ϕ - Capacity Reduction Factor

θ - Stability Coefficient Used to Measure the significance of P-Delta effects

3.0 DEFINITIONS

Anchor – A steel element either cast into concrete or masonry or post installed into a hardened concrete or masonry member. Including headed bolts, hooked bolts (J- or L- bolt), headed studs, expansion anchors, or undercut anchors. Anchors in the context of the ESM also include steel to steel connection elements and welds. Anchors are used to transmit applied loads.

Attachment – The structural assembly, external to the surface of the concrete that transmits loads to or receives loads from the anchor.

Bearing wall system – A structural system without a complete vertical load-carrying space frame. Bearing walls provide support for some of the gravity loads. Resistance to lateral load is provided by shear walls or braced frames, which also provide resistance to gravity loads.

Cast-in Place Anchor – A headed bolt, headed stud, or hooked bolt installed before placing concrete.

Component (non-structural) – An item of equipment, such as a pump, valve or relay, or an element of a larger array, such as a length of pipe, elbow, or reducer

Collector Elements – A diaphragm or shear wall element parallel to the applied load that collects and transfers shear forces to the vertical-force-resisting elements or distributes forces within a diaphragm or shear wall.

Critical Damping – Level of damping at which no oscillations of dynamic response occur.

Distribution System – A system whose function is to distribute material (fluid, signals, power).

Dual system – A structural system with the following features: An essentially complete space frame that provides support for gravity loads, resistance to lateral load is provided by shear walls or braced frames or moment-resisting frames (SMRF, IMRF, MMRWF or steel OMRF) with the moment-resisting designed to independently resist at least 25 percent of the design base shear, and the two systems designed to resist the total design base shear in proportion to their relative rigidities considering the interaction of the dual system at all levels.

Edge Distance – The distance from the edge of the concrete surface to the center of the nearest anchor. Also, the distance from the edge of a steel plate to the center of the nearest anchor bolt.

Effective Stiffness Factor – Modifier (e.g., 0.5, 0.8) that is applied to the uncracked section properties of a reinforced concrete member to account for the softening effect that cracking has.

Embedment Depth – The overall depth through which the anchor transfers force to or from the concrete by direct bearing or friction or both. The embedment depth is measured from the bearing contact surface of the bolt end to the top of concrete.

Exceedance Frequency – The annual probability of exceeding a given ground motion. For example, at LANL, the mean exceedance frequency associated with a peak ground acceleration of .34g is 4×10^{-4} (i.e., 1/2500) or an average return period of 2500 years.

Existing Facility – A facility that has received authorization to operate on or before the effective date of this ESM Chapter, or if authorization is not required, a facility that has begun normal operation on or before the effective date of this ESM Chapter.

Expansion Anchor – A post-installed anchor, inserted into hardened concrete that transfers loads to or from the concrete by direct bearing or friction or both. Expansion anchors may be torque-controlled, where the expansion is achieved by a torque acting on the screw or bolt; or displacement-controlled, where the expansion is achieved by impact forces acting on a sleeve or plug and the expansion is controlled by the length of travel of the sleeve or plug.

Facility – One or more building(s) or structure(s), including systems and components, dedicated to a common function (includes operating, non-operating, and facilities slated for decontamination and decommissioning).

Fragility – A conditional cumulative probability density function related to failure or other dysfunction limit. The function is often related to a key parameter, such as PGA (or sometimes spectral acceleration or displacement) associated with failure level.

F_μ - Inelastic Energy Absorption Factor – A factor used to reduce linearly estimated demand to account for limited inelastic behavior in PC-3 and PC-4 SSC's. The Inelastic Energy Absorption Factor is a function of the target limit state and the structural system configuration.

Graded Approach – A process by which the level of analysis, documentation, and actions necessary to comply with requirements are commensurate with: the relative importance to safety, safeguards, and security; the magnitude of any hazard involved; the life cycle stage of a facility; the programmatic mission of a facility; the particular characteristics of a facility; and any other relevant factor.

Hazard – A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to an operation or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation).

Headed Stud – A steel anchor conforming to the dimensional specifications in AWS D1.1 consisting of a steel rod with a larger diameter head on its end for providing mechanical anchorage in concrete. Applications are for attaching steel base plates or embedded steel plates to concrete or to effectively tie the concrete to the steel beams and to resist shear loadings between the concrete slab and steel beam in composite construction. The head of the anchor typically has a diameter equal to twice that of the rod.

HCLPF – High Confidence of Low Probability of Failure, usually a 90% confidence of a less than 10% probability of failure which results in about a 1% to 2% probability of failure

Hooked Bolt – A cast-in anchor anchored mainly by mechanical interlock from the 90-degree bend (L-bolt) or 180-degree bend (J-bolt) at its lower end.

Headed Stud – A steel anchor conforming to the requirements of AWS D1.1 and affixed to a plate or similar steel attachment by the stud arc welding process before casting.

Item – Structural component, structure, system or component (see individual definitions).

Limit State – The limiting acceptable condition of the SSC. The limit state may be defined in terms of a maximum acceptable displacement, strain, ductility, or stress.

Load Path – The path of resistance consisting of structural or non-structural members that an imposed load will follow from the point of origin (inertial forces at location or structure mass) to the point of final resistance (supporting soil).

Mean Annual Hazard – The expected (or average) exceedance frequency associated with a given hazard. Future seismic loads are highly variable. For a given site, there is typically, a "mean annual seismic hazard" curve that expresses the average (or expected) value of a ground motion parameter, such as peak ground acceleration, as a function of the probability of exceedance of that variable.

Moment Resisting Frame System – A structural system with an essentially complete space frame providing support for gravity loads. Moment-resisting frames provide resistance to lateral load primarily by flexural action of members.

P-Delta (P-Δ) Effect – Additional moment induced in axial load carrying members caused by structural deformation of the joints. The P-Delta moment is the product of the axial force and the relative displacement between the end points of the member.

PGA – Peak Ground Acceleration – The maximum absolute value of the ground acceleration time history.

Peak Spectral Acceleration – The maximum acceleration response that a prescribed forcing function can produce in a single degree of freedom oscillator (independent of the natural frequency of the oscillator).

Peer Review – A formal review process in which an external party (independent from the project) will review the methodology, results, and process by which a design is developed.

Pinched Hysteretic Behavior –A characteristic of the load-deformation loop of a structural component subjected to cyclic loading that is marked by both strength and stiffness degradation in successive loading and unloading cycles beyond yield. See example below.

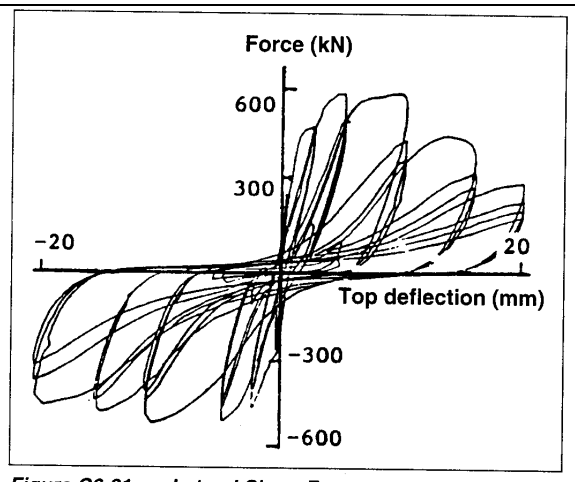


Figure C6-21 Lateral Shear Force versus Top Displacement of Shear Wall Specimen 1

Plan Structural Irregularity – Structural irregularity at a given floor level in the building due to unsymmetric mass or stiffness.

Plastic Hinge Length – Region of plastic deformation, may be approximated by a length equal to one beam depth.

Post-installed anchor – An anchor installed in hardened concrete. Expansion anchors and undercut anchors are examples or post-installed anchors.

R – Response Modification Coefficient – A factor used to reduce demand to account for limited inelastic behavior and other factors (e.g., overstrength, redundancy) in PC-1 and PC-2 SSC's. The Response Modification Coefficient is a function of the structural system configuration.

RRS - Required Response Spectra – The representation of the response spectra that are required to qualify an structure, system or component. The required response spectra will often include factors of conservatism required to meet probabilistic performance goals.

Safety Class – A category for facilities or structures, systems, and components identified by a safety analysis whose importance to safety is to prevent or mitigate potential adverse consequences to the general public or the environment.

Safety Significant – A category for facilities or structures, systems, and components identified by a safety analysis whose importance to safety is to prevent or mitigate potential adverse consequences to the facility workers or occupants.

Seismic Capacity – The capacity of a structure, system or component to withstand the loadings imposed on them from an earthquake. The capacity is a combination of the structures strength and ductility.

Seismic Demand – The demand imposed on the structure, system, or component being evaluated at the earthquake level under consideration. The seismic demand may be a force or a displacement.

Seismic Hazard Curves (HC) – Description of the ground motion parameter of interest as a function of annual frequency of exceedance. Peak ground acceleration and spectral accelerations at 0.2 sec and 1 second natural period plotted as a function of annual frequency of exceedance are common. The seismic hazard curves are determined from a probabilistic hazard assessment following the guidance in DOE-STD-1022 and DOE-STD-1023.

Significant – Greater than a 5% increase in the response item of interest.

SMRF – Special Moment Resisting Frame - Also known as special moment frame, is a moment-resisting frame specially detailed to provide ductile behavior and comply with the requirement given in AISC Seismic Provisions, and the IBC

Spectral Acceleration – The maximum acceleration response of a single-degree or freedom oscillator of a know frequency, f and viscous damping, β, subjected to a prescribed forcing function.

Structural Element – Portion of a structure such as a beam column, brace, anchor or support (pipe or cable tray, etc.).

Structural Lead Engineer – Engineer appointed to lead the structural design activities for a project.

Structure – An element or a collection of elements, to provide support or enclosure, such as a building, free standing tanks, basins, dikes or stacks.

System (non-structural) – A collection of components assembled to perform a plant function. For example the Service Water System would be composed of the pumps, piping, valves, electrical equipment (providing power to the pumps) and cable tray and conduit used to transport that power.

TRS – Test Response Spectra – Response spectra specified for the seismic qualification test of an equipment item. The TRS is specified to envelope the RRS.

TNT – Trinitrotoluene - toxic flammable, explosive yellow crystals used as an explosive intermediate. Lbs of TNT is used as a general measure of detonation intensity for all types of explosive sources.

Undercut Anchor – A post-installed anchor that develops its tensile strength from the mechanical interlock provided by undercutting of the concrete at the embedded end of the anchor. The undercutting is achieved with a special drill before installing the anchor or alternatively by the anchor itself during its installation.

Vertical Structural Irregularity – Significant differences in stiffness or mass from one story of a structure to another.

Zero Period Acceleration (ZPA) – Same as PGA. The maximum absolute value of the ground or in-structure acceleration time history record.

4.0 REFERENCES

[1] DOE-STD-1020, "Natural Phenomena Hazards Design and Evaluation Criteria for DOE Facilities", January 2002.

[2] DOE-STD-1021, "Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems and Components", April 2002.

[3] DOE-STD-1027, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23 Nuclear Safety Analysis Reports", September 1997.

[4] DOE-STD-3009, "Preparation Guide for US DOE Non-Reactor Nuclear Facility Analysis", January 2000.

[5] International Building Code – 2003 (IBC), Copyright 2002, First Printing December 2002.

[6] ASCE 4, "Seismic Analysis of Safety Related Nuclear Structures and Commentary", 1998.

[7] ASME Boiler and Pressure Vessel Code, Section III, Division 1, 2001.

[8] DOE/EH-0545, "Seismic Evaluation Procedure for Equipment in the US DOE Facilities", March 1997.

[9] ASME QME-1, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants", 1997.

[10] IEEE 344, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations", 1997.

[11] ASCE 7, "Minimum Design Loads for Buildings and Other Structures" - 2002.

[12] AISC, "Manual of Steel Construction Allowable Stress Design", Ninth Edition, 1989.

[13] AISC, "Manual of Steel Construction Load & Resistance Factor Design", Third Edition, 2001.

[14] DOE, "Nuclear Safety Management", 10 CFR Part 830.

[15] DOE, "Quality Assurance", DOE Order 414.4 (CHG 1), July 2001.

[16] ACI 318, "Building Code Requirements for Structural Concrete", Code and Commentary, 2002.

[17] ACI 530, "Building Code Requirements for Masonry Structures", Code and Commentary, 2002.

[18] ANSI/AISC 341, “Seismic Provisions for Structural Steel Buildings”, May 21,2002.

[19] ANSI/AISC N690, “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities”, Code and Commentary, 1994, with Supplement No. 1, ANSI/AISC N690-1994s1, April 2002.

[20] ACI 349, “ Code Requirements for Nuclear Safety Related Concrete Structures”, Code and Commentary, 2001.

[21] DOE-STD-1022, “Natural Phenomena Hazards Site Characterization Criteria”, March 1994.

[22] Special Publication ARLCD-SP-84001, Structures to Resist the Effects of Accidental Explosions, 6 Volumes, Department of the Army Technical Manual, TM 5-1300, 19 November 1990.

[23] Electrical Power Research Institute (EPRI) Report NP-6041-SL, A Methodology for Assessment of Nuclear Power Plant Seismic Margins.

[24] Electrical Power Research Institute (EPRI) Report TR-103959, Methodology for Developing Seismic Fragilities.

[25] Brookhaven National Laboratory Report BNL-52361, Seismic Design and Evaluation Guidelines for the DOE High-Level Waste Storage Tanks and Appurtenances.

[26] WSRC Bulletin No 425, A Review of Methods for the Analysis of Buried Pressure Piping.

[27] Adams, T.M., et. al., A Proposed Procedure for Buried Safety Related Piping at Nuclear Power Facilities, Presented at the 1998 ASME PVP Conference, San Diego, CA.

[28] Woodward-Clyde Federal Services, Final Report- Seismic Hazards Evaluations of the Los Alamos National Laboratory for Los Alamos National Laboratory, Rept. Eng-MPD-93-BCMR.

[29] Goen, Roe, LANL Memorandum to Doug Volkman, Time Histories - LANL PC3 Design Basis Earthquake, ESA-EA:97-130, Los Alamos National Laboratory, Los Alamos, New Mexico.

[30] NMT-CMRU Document, “Engineering Calculations”, Document Number: CMRU-AP-002, 5/24/1999.

[31] Facility and Waste Operations Division, “Calculations”, FWO-DO Procedure – 603, Rev. 0, Nov. 16, 2001.

[32] DOE/TIC–11268, " A Manual for the Prediction of Blast and Fragment Loading of Structures, " U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79210.

[33] Bowen, Brent M., LA-11735-MS, UC-902, "Los Alamos Climatology", May 1990.

[34] American Forest & Paper Association, "National Design Specification (NDS) for Wood Construction (ANSI/AF&PA NDS-2001)", including its supplements and provisions, 2001.

[35] American Forest & Paper Association, "Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction", AF&PA/ASCE 16-95, 1996.

[36] The Aluminum Association, "Aluminum Design Manual", 2000 Edition.

[37] DOE/RW-033P, "Quality Assurance Requirements and Description (QARD) for Civil Radioactive Waste Management, Rev. 8.

[38] American Consulting Engineers Council/American Society of Civil Engineers, New York, New York, 1990.

[39] ASCE, Manuals and Reports on Engineering Practice – No. 58, "Structural Analysis and Design of Nuclear Plant Facilities", 1980.

[40] DOE, "Facility Safety", DOE Order 420.1, Washington D.C., October 13, 1995.

[41] FEMA-368, "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures", Part 1 – Provisions, 2000 Edition including the September 4, 2001 Errata.

[42] EPRI Report NP-5228, Revision 1, "Seismic Verification of Nuclear Plant Equipment Anchorage", Volume 1, Electric Power Research Institute, Palo Alto, California, prepared by URS Corporation / John A. Blume & Associates, Engineers, June 1991.

[43] ASCE – Dynamic Analysis of Nuclear Structures Subcommittee of the Nuclear Standards Committee, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities and Commentary," Draft, November 2002.

[44] ASCE – Task Committee on Blast Resistant Design, "Design of Blast Resistant Buildings in Petrochemical Facilities," American Society of Civil Engineers, 1997.

[45] CCPS, "Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs", Center for Chemical Process Safety, American Institute of Chemical Engineers, 1994.

[46] DoD – Unified Facilities Criteria (UFC), "DoD Minimum Antiterrorism Standards for Buildings," UFC 4-010-01, U.S. Department of Defense, July 31, 2002.

[47] ICBO, "Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components," AC156, ICBO Evaluation Service, Inc., Whittier, CA, January 2000.

[48] Subsurface Investigation for Design and Construction of Foundations of Buildings, ASCE Manual No. 56, ASCE 1976.

[49] Site Investigations for Foundations of Nuclear Power Plants, U.S. Nuclear Regulatory Commission Regulatory Guide 1.132, Revision 1, March 1979.

[50] Canadian Foundation Engineering Manual, Canadian Geotechnical Society, 2nd edition, 1985.

[51] NAVFAC Design Manuals (DM) 7.1, 7.2 and 7.3, Department of the Navy, Naval Facilities Engineering Command, Alexandria, VA 1982.

[52] Geotechnical Investigations, Engineering and Design, Department of the Army Corps of Engineers, Office of the Chief of Engineers.

[53] ASCE, American Society of Civil Engineers, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," SEI/ASCE 8-02, 2002.

[54] ASCE, American Society of Civil Engineers, "Structural Applications of Steel Cables for Buildings," ASCE 19-96, 1996.

[55] American Concrete Institute (ACI), "Building Code Requirements for Masonry Structures," ACI 530/ASCE 5/TMS 402 and "Specifications for Masonry Structures," ACI 530.1/ASCE 6/TMS 602, 1999.